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ABSTRACT

This report presents findings of a National Science Foundation (NSF) assessment of the adequacy of the supply of science, engineering, and technician (SET) personnel for meeting defense and non-defense requirements between 1982 and 1987. Selected findings included in the report follow. Based on four scenarios representing combinations of low and high macroeconomic activity, employment growth in the major employment categories (science, engineering, technician) is projected to range from 2.5 percent to 4.0 percent per year. Shortages are projected for aeronautical/astronautical engineers and computer specialists. At high projected levels of defense expenditures, the shortage of electrical/electronic engineers will be almost 10 percent of supply or roughly 30,000 personnel. Employment of electrical/electronic engineering technicians is projected to increase from 3.0 percent to 4.0 percent annually over the next 4 years, and employment for mechanical engineering technicians is projected to increase by 2.4 percent to 5.0 percent. Projections of SET employment were more sensitive to variations in defense spending that to variations in macroeconomic activity because the former's impact is concentrated on high-technology, manufacturing industries. Among SET occupations, defense expenditures have their strongest impact on the engineering work force. (JN)

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SCIENCE RESOURCES STUDIES HIGHLIGHTS

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Projected Employment Scenarios Show Possible Shortages in Some Engineering and Computer Specialties

This report presents findings of a National Science Foundation (NSF) assessment of the adequacy of the supply of science, engineering, and technician (SET) personnel for meeting defense and nondefense requirements between 1982 and 1987.

Employment requirements for this study were projected using NSF-generated SET data in conjunction with the Defense Interindustry Forecasting System (DIFS) developed by Data Resources, Incorporated (DRI). Four sets of employment projections were generated based on varying assumptions of macroeconomic activity and defense-expenditure levels. These projections were designed to provide a range of employment that should encompass actual requirements over this period.

Estimates of supply in science and engineering (S/E) occupations were derived from a stock-flow model developed under contract to NSF by Drs. Robert DauffenBach (Oklahoma State University) and Jack Fiorito (University of Iowa). The model projects the response of three components of supply (new labor force entrants, immigrants, and experienced workers) to variations in employment demand. In this analysis, growth in supply is restricted to new entrants and immigrants. This restriction understates the degree of flexibility in the SET labor force and thus overstates potential imbalances. A subsequent report will waive this restriction to assess the role of occupational mobility in alleviating shortfalls in supply.

Highlights

- Four scenarios were evaluated for the 1982-87 period representing combinations of low and high macroeconomic activity--annual growth rates in gross national product (GNP) of 1.6 percent and 4.3 percent, respectively—and low and high growth rates in real defense expenditures—annual growth rates of 3.1 percent and 8.1 percent, respectively. Based on these scenarios, employment growth in each of the major occupational categories—science, engineering, and technician—is projected to range from 2.5 percent to 4.0 percent per year.
- Shortages (representing at least a 10-percent shortfall in supply) are projected for aeronautical/astronautical engineers and computer specialists. By 1987, the shortfall for the former will vary from 15 percent to 45 percent, representing approximately 10,000 to 35,000 personnel; for the latter, the comparable range will be 15 percent to 30 percent, or about 115,000 to 140,000 personnel. At high projected levels of defense expenditures, the shortfall of electrical/electronic engineers will be almost 10 percent of supply or roughly 30,000 personnel. Increasing job opportunities and wage incentives can be expected to draw workers into these fields, helping to alleviate potential problems.
- Employment of electrical/electronic engineering technicians is projected to increase from 3.0 percent to 4.0 percent annually over the next five years; that for mechanical engineering technicians is projected to increase by 2.4 percent to 5.0 percent. Both sets of growth rates exceed those noted at the end of the seventies. Qualifications of technicians vary considerably, making it impossible to generate meaningful supply projections. Thus, although these occupations merit observation, it is not entirely clear whether such growth in demand will produce problems.
- Projections of SET employment were more sensitive to variations in defense spending than to variations in macroeconomic activity because the former's impact is concentrated on high-technology, manufacturing industries. Among SET occupations, defense expenditures have their strongest impact on the engineering work force.

Introduction

Although it constitutes only 3 percent of the 1982 labor force, the SET work force exerts a strong influence on industries critical to maintaining national security, general economic growth, and technological innovation.[1] Major Government initiatives in these areas and the SET labor market are highly interdependent. On the one hand, such initiatives can be expected to have a significant impact on this labor market; on the other, the efficient functioning of this market has a definite bearing on the outcomes of these initiatives. For

[1] Employment projections used in this analysis are based on the Bureau of Labor Statistics' establishment-based Occupational Employment Statistics (OES) survey.

Prepared in the Utilization Studies Group, Division of Science Resources Studies

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this reason, NSF has conducted a study to determine whether the SET labor market can support demands generated by the proposed increase in defense spending.

Under the Administration's proposed Five-Year Defense Plan, real defense expenditures are projected to increase by roughly 50 percent between 1982 and 1987.[2] Defense spending, predominately targeted on high-technology industries, requires large numbers of skilled personnel. An earlier analysis of the effect of Federal expenditures on S/E employment indicated that, in the seventies, defense spending generated three times the demand for S/E workers as expenditures for nondefense needs.[3] This result probably understates the current impact of defense spending, however, because of the increasing sophistication of weapons systems and the growing share of the defense budget going toward procurement, research, development, and testing.[4]

Defense demands for skilled personnel will have to compete with private sector requirements. While the demand for SET workers has moderated significantly in 1982 in response to a weakening of the economy, this situation can easily be reversed when economic recovery begins in earnest and past employment trends are resumed.[5] The potential strength of this demand can be discerned from the increasing utilization of SET personnel in manufacturing industries, which form the core of demand for these occupations. At the beginning of the eighties, growth in SET employment in these industries outpaced that of the overall work force by more than 6 to 1.[6] This pattern of demand will undoubtedly be renewed when the economy recovers as a result of the growing importance of high-technology industries; the increasing emphasis on productivity and international competitiveness; and the rapid diffusion of computer technology.

Projection Scenarios

Four scenarios based on varying assumptions about levels of macroeconomic activity and defense expenditures were used to generate demand projections for this analysis (table 1).[7] The two scenarios based on the high-economic growth assumption (OPTIM) are predicated on a vigorous economic recovery in 1983 and 1984, which moderates in subsequent years. Strong economic performance in these scenarios is directly related to maintaining a low average annual rate of inflation (6 percent). Between 1983 and 1987, the annual growth rate in real GNP (roughly 4 percent) is projected to be significantly higher than rates achieved in the early eighties; the same is true for the projected annual rate of productivity growth (2 percent). The two scenarios based on a low-economic growth assumption (STAG) assume that the economic performance of the early eighties will continue through 1984, after which time a modest recovery will occur. The STAG scenarios assume that the annual rate of inflation (7 percent) will remain above current levels and that only modest gains in the annual growth rates of real GNP (2 percent) and productivity (1 percent) will be achieved.

The high defense spending assumption (HIGH) is based on implementation of the Administration's Five-Year Defense Plan as proposed for the period beginning in fiscal year 1983. Under this plan, real defense expenditures increase at a compounded annual rate of about 8 percent over the next five years. The low defense spending assumption (LOW) constrains growth in defense expenditures to about 3 percent over the same period. Under the latter assumption, personnel and retirement expenditures are maintained at levels proposed in the Administration's plan and reductions in the growth of defense spending are confined to categories such as procurement, operations and maintenance, and research, development, and testing.

Projected Range of SET Employment

Macroeconomic activity and defense expenditures affect SET employment through their impact on the level and pattern of industrial production. The four scenarios that form the basis of this analysis indicate a relatively narrow range of projected employment in major SET categories over the next five years. Based on the STAG/LOW and OPTIM/HIGH scenarios which define the maximum range in demand, sci-

Table 1. Summary statistics for macroeconomic/defense expenditure scenarios: 1983-87

Macroeconomic indicators	STAG/LOW	STAG/HIGH	OPTIM/LOW	OPTIM/HIGH
Average annual rates of change:				
Defense expenditures, constant dollars	3.1	8.1	3.1	8.1
Gross national product, constant dollars	1.6	2.2	3.5	4.3
Industrial production index	2.2	3.0	5.3	6.6
Productivity, output per hour	1.1	1.2	1.8	2.0
Consumer price index	7.2	7.4	6.1	6.4
Average annual unemployment rate	10.5	9.8	7.3	6.6

NOTE: STAG/LOW indicates the low-economic growth/low-defense spending scenario; STAG/HIGH indicates the low-economic growth/high-defense spending scenario; OPTIM/LOW indicates the high-economic growth/low-defense spending scenario; and OPTIM/HIGH indicates the high-economic growth/high-defense spending scenario.

SOURCE: National Science Foundation.

[2] Caspar W. Weinberger, *FY 83 Annual Report to Congress* (Washington, D.C.: Supt. of Documents, U.S. Government Printing Office, February 8, 1982).

[3] Department of Labor, *The Effects of Federal Expenditures on Scientific and Technical Manpower Requirements* (Washington, D.C.: Supt. of Documents, U.S. Government Printing Office, 1975).

[4] Data Resources, Incorporated, "The 1983 Defense Budget: Contents, Contexts, and Consequences," *Defense Economics Research Report*, Vol. II, No. 3, March 1982.

[5] National Science Foundation, "Labor Market Slackens for New Science and Engineering Graduates," *Science Resources Studies Highlights* (NSF 82-309) (Washington, D.C., November 22, 1982).

[6] National Science Foundation, *Changing Employment Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries: 1977-80* (NSF 82-311) (Washington, D.C., 1982).

[7] The DIFS model is the commercial version of the Defense Economic Impact Modeling System (DEIMS), a collaborative effort of DRI and the Department of Defense. Model documentation can be found in Department of Defense, Office of the Secretary of Defense, *Defense Economic Impact Modeling System* (Washington, D.C., July 1982). Documentation of the supply model can be found in Robert DanffenBach and Jack Fiorito, "Projections of the Supply of Scientists and Engineers: 1982-87," NSF Contract No. SRS-82-16546 (Stillwater, Okla.: Oklahoma State Univ., 1983).

ence employment is projected to increase at an average annual rate of 3.0 percent to 4.3 percent, to a 1987 projected level of 850,000 to 900,000 (chart 1). For engineering occupations, the projected annual growth rate ranges from 2.7 percent to 4.2 percent, generating a projected employment of 1,300,000 to 1,400,000 in 1987. For technicians, the projected growth of 2.3 percent to 3.3 percent per year leads to employment of 1,650,000 to 1,750,000.

The narrow range of projected employment levels was predominately the result of the more rapid productivity increases assumed under the high-growth macroeconomic assumptions. While output expands rapidly in the OPTIM scenarios, the need for additional personnel is dampened by increasing output per employee. Lower assumed rates of productivity growth would have generated greater employment demand and a wider range of likely estimates. The impact of macroeconomic activity on individual occupations can vary significantly depending on demand patterns across industries.[a] The pattern of economic activity over the next five years, however, is projected to have a roughly comparable effect for major SET occupational categories; the demand for engineers and technicians is only slightly more affected than that for scientists.

Despite the relatively small proportion of GNP going to defense expenditures (from 5 percent to 7 percent across scenarios), variation in the assumed levels of defense spending had the same impact on SET employment demand as variations in activity across the entire economy. Defense spending, however, most directly affects demand in engineering occupations.

Projected S/E Labor Market Imbalances

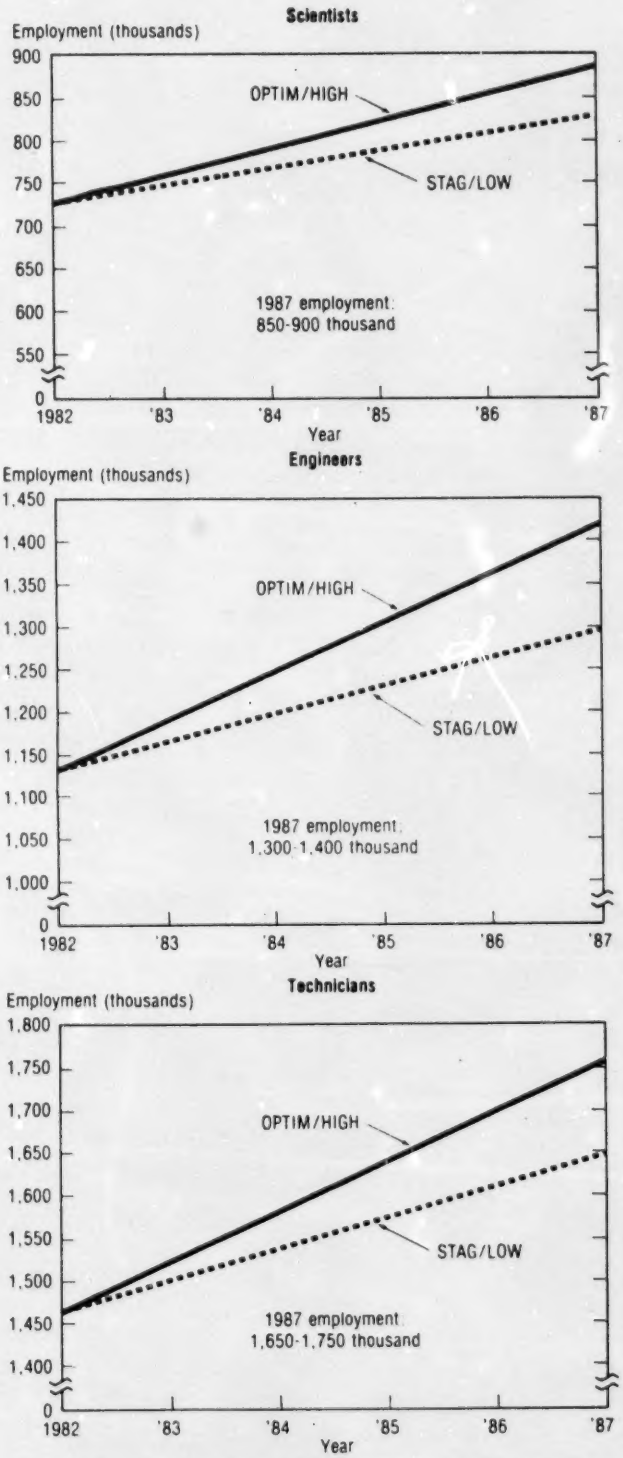
Probable Shortage Fields

Aeronautical/astronautical engineers—Employment in aeronautical/astronautical engineering is projected to increase at an average annual rate of 6 percent to 11 percent over the next five years (chart 2). Defense-related demand is an important factor contributing to this rapid growth since more than two-fifths of these engineers are employed on defense-related projects. Demand requirements are expected to outpace additions to supply in this occupation (table 2). By 1987, shortages are projected to range from 15 percent in STAG/LOW to 45 percent in OPTIM/HIGH indicating a possible need for an additional 10,000 to 35,000 personnel.

Computer specialists—Over the next five years, employment in computer specialties (systems analysis and programming) are projected to grow at an annual rate of 5 percent to 6 percent. Over this period, regardless of scenario, growth in supply is projected to fall behind that for demand leading to an increasing shortage in the years ahead. By 1987, the projected supply shortfall ranges from 15 percent in STAG/LOW to 30 percent in OPTIM/HIGH. These shortages translate into a possible need for 115,000 to 140,000 additional personnel in that year. These projections may, however, overstate potential shortages because such occupations are characterized by a highly flexible supply of workers.

[a] The effects of defense spending on SET employment is similar regardless of the assumed level of economic growth; similarly, the effect of macroeconomic conditions on SET employment is independent of the level of defense expenditures.

Chart 1. Projected range of employment in science, engineering, and technician occupations: 1982-87[a]

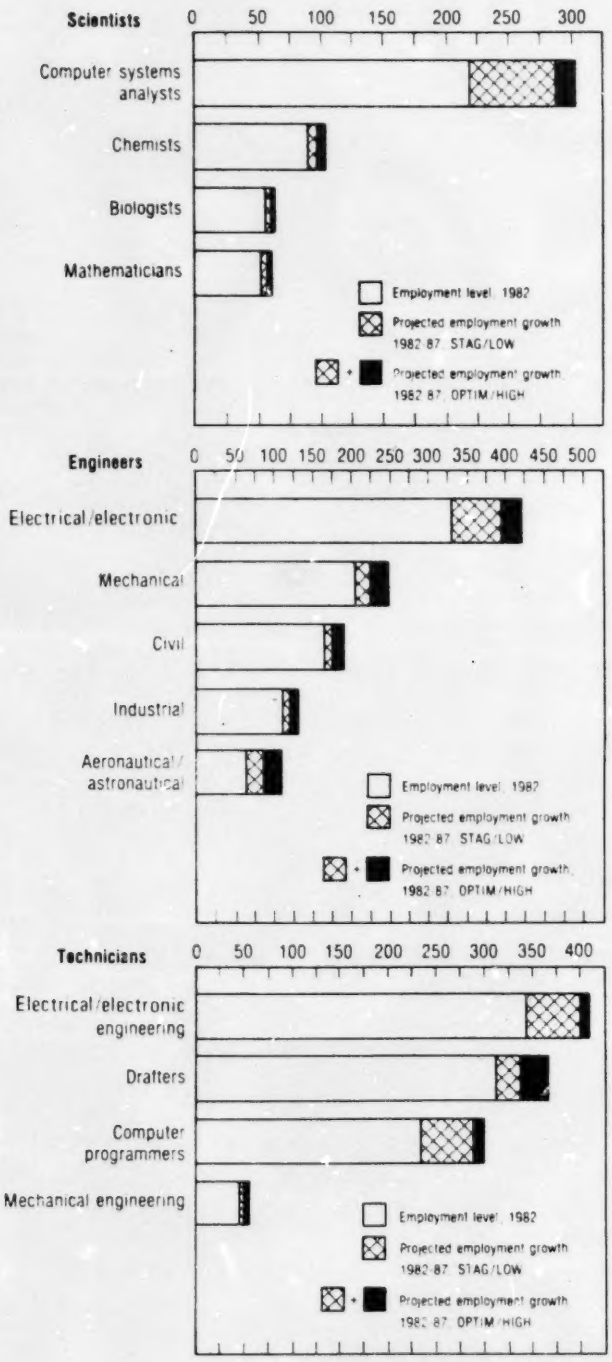


[a] Employment ranges are derived using the average annual growth rates in each of the scenarios given. Actual employment estimates are anticipated to fall within this range only if all assumptions are met.

NOTE: OPTIM/HIGH indicates the high-economic growth/high defense spending scenario and STAG/LOW indicates the low-economic growth/low defense spending scenario.

SOURCE: National Science Foundation

Chart 2. Projected employment in major science, engineering, and technician occupations: 1982-87



NOTE: STAG/LOW indicates the low-economic growth/low-defense spending scenario and OPTIM/HIGH indicates the high-economic growth/high-defense spending scenario.

SOURCE: National Science Foundation.

Table 2. Projected demand/supply balance in science/engineering occupations: 1987

Occupation	STAG/LOW	OPTIM/HIGH
Scientists		
Agricultural	No shortage	No shortage
Biologists	No shortage	No shortage
Chemists	No shortage	No shortage
Computer specialists[1]	Shortage	Shortage
Geologists	No shortage	No shortage
Mathematicians	No shortage	No shortage
Physicists	No shortage	No shortage
Social	No shortage	No shortage
Engineers		
Aeronautical/ astronautical	Shortage	Shortage
Chemical	No shortage	No shortage
Civil	No shortage	No shortage
Electrical/electronic	No shortage	Potential shortage
Industrial	No shortage	No shortage
Mechanical	No shortage	No shortage
Metallurgical	No shortage	No shortage
Mining/petroleum	No shortage	No shortage
Engineering, n.e.c.	No shortage	No shortage

[1]Includes both computer systems analysts and programmers.

NOTES: Shortage occupations have projected supply estimates which deviate from projected demand by 10 percent or more; potential shortage occupations have a projected supply of workers deviating from the projected level of demand by 5 to 10 percent.

STAG/LOW indicates the low-economic growth/low-defense spending scenario and OPTIM/HIGH indicates the high-economic growth/high-defense spending scenario.

SOURCE: National Science Foundation.

Expanding job opportunities and wage incentives can be expected to attract workers to these occupations.

Potential Shortages

Electrical/electronic engineers—Employment of these engineers is expected to increase at an average annual rate of 4 percent to 5 percent between 1982 and 1987. Increments to supply based on new labor force entrants and immigrants are adequate to balance projected employment in this field at low levels of defense spending. When defense expenditures are high, however, supply is barely adequate and, by 1987, a potential shortage of up to 30,000 personnel could arise.

Industrial engineers—Industrial engineering employment is projected to increase at an annual rate of 2 percent to 4 percent over the next five years. No shortages are expected at these rates of growth. Evidence suggests, however, that projected employment growth in this occupation may be understated because projected trends in SET staffing assumed in the DIFS model fail to capture the recent accelerated growth in industrial engineering jobs. Such growth has resulted from industry's emphasis on productivity, cost containment, and quality control.[9] If this is the case, supply constraints in this occupation could result.

[9]National Science Foundation, *Changing Employment Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries*, op. cit.

Technician Occupations

The supply of technicians is difficult to measure because formal training cannot be used as a means of identifying the population available to fill these jobs. For these occupations, there is no model of supply. Therefore, actual 1976-81 and projected 1982-87 employment growth rates were compared to identify potential constraints (table 3).

Table 3. Projected versus actual growth in technician occupations
[Percent]

Technician occupation	STAG/ LOW 1982-87	OPTIM/ HIGH 1982-87	Actual 1976-81[1]
Drafters	1.6	3.3	6.4
Electrical/electronic engineering	3.0	4.0	2.8
Industrial engineering	1.8	3.6	6.7
Mechanical engineering	2.4	5.0	1.8
Other engineering	1.5	2.9	4.8

[1] Based on Department of Labor's Current Population Survey (CPS)

NOTE: STAG/LOW indicates the low-economic growth/low-defense spending scenario and OPTIM/HIGH indicates the high-economic growth/high-defense spending scenario.

SOURCE: National Science Foundation

In both electrical/electronic and mechanical engineering technician occupations, growth rates in employment over the next five years are projected to exceed those noted in the recent past. Actual annual employment growth in the former (2.8 percent) barely keeps pace with the growth at the lower end of the projection range (3.0 percent to 4.0 percent). For the latter, actual annual growth (nearly 1.8 percent) falls even farther below the projected range (2.4 percent to 5.0 percent).

The results are ambiguous, however, and whether a shortage is indicated depends on causes for the lower growth rates in the past. If low employment growth was the result of inadequate supply of such personnel, the accelerated growth in demand projected for the next five years may exacerbate an existing shortage situation. If, on the other hand, low employment growth resulted from weak demand for such skills, the likelihood of a shortage depends on the ability of employers to attract new workers to this field and the amount of time needed to train these individuals. Because of such uncertainties, these particular occupations merit observation.

Limitations to Analyses of Labor Market Imbalance

Assessment of labor market imbalances is extremely complex and some limitations to this type of analysis should be stated.

First, it must be realized that the projected ranges of SET employment in these scenarios are not predictions; instead, they show what might occur under the many assumptions discussed. Departures from these assumptions may alter projections significantly.

Second, models are restricted by data availability to major occupational categories. Analysis of these categories may fail to identify subspecialties which are in shortage or oversupply.

Third, while the supply of workers may be considered adequate in some occupations, it may not always be of suitable quality to meet employers' needs. For example, if experienced personnel are needed but only new entrants to the labor force are available, employers must bear the cost of reduced output and training. The same type of problem exists for experienced workers who change occupations. Labor market adjustments have costs which are significant to employers in terms of quality, production delays, and inflation.

Finally, shortages can have a serious effect on those sectors, like academia, which cannot effectively compete with the higher salaries and state-of-the-art equipment available in industry. While defense industries will probably obtain the personnel they need to execute the defense plan, the cost to other sectors may be substantial.

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A final report on this subject will be published in 1983.